Ansys Transient Thermal Analysis of the Hall C Neutral Particle Spectrometer's Lead Tungstate Crystals

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This note presents the results of the Ansys transient thermal analysis of the Neutral Particle Spectrometer (NPS) lead tungstate crystal array and compares these results with the results of the previously conducted Ansys steady state thermal analysis.

The NPS crystal array has 36 rows and 30 columns of lead tungstate crystal blocks, each crystal block measuring 200 mm x 20 mm x 20 mm and each connected to a Hamamatsu photomultiplier tube (PMT) (R41253355027), which in turn is connected to a divider base. A model with 1080 crystals, carbon fiber dividers, and mu-metal dividers was created using Ansys DesignModeler to simulate the temperature profile of the crystal array, and to verify whether the engineered cooling design could maintain the temperature of the crystals at ~18°C ± 1°C for optimum efficiency [1, 2].

Initial simulations performed were steady state simulations in which the energy source had been active for a sufficient length of time for the system to reach thermal equilibrium; the steady state analysis does not provide information on how the system behaves as it evolves to the equilibrium state.

For the steady state simulation, parameters were chosen such that each body of the model had a convection rate of 5 W/m^2·°C, the ambient temperature was set to 20°C, and the copper cooling shell was set to 10°C. Based on the expected operating high voltage of 605 V and low voltage of 4.5 V, with operating currents of 405 µA and 18 mA per PMT channel, respectively, a heat load of 0.3 W was applied to the rear face of each crystal. The results of the steady state simulation showed that, despite the engineered cooling design, the temperature of the central crystals (about 11% of the crystals) is at 18°C ± 1°C.

Next, a transient thermal simulation, which allows the temperature to fluctuate during the simulation and provides a snapshot of the temperature profile for the system as it approaches thermal equilibrium, was performed.

The transient thermal simulation was run for 48 hours using the same parameter settings (except for the meshing) as the steady state simulation. Results of the transient simulation showed a smaller central region of crystals with maximum temperature ~15.32°C, Fig. 1. From the data of the transient simulation, maximum temperatures were plotted as a function of time, Fig. 2.

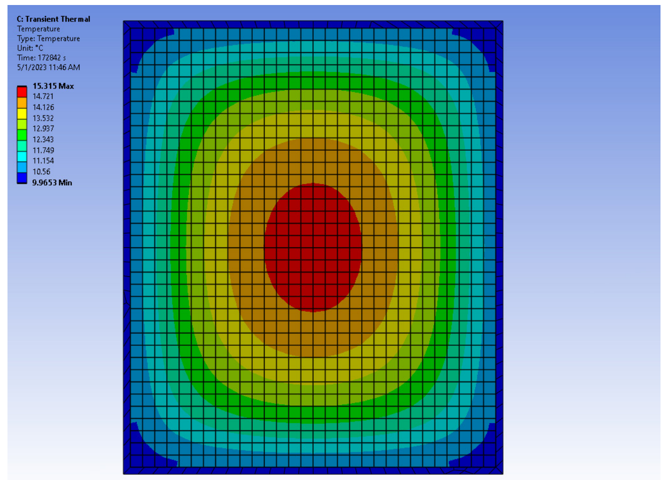

FIG. 1. Ansys Transient thermal simulation (~48 hrs).

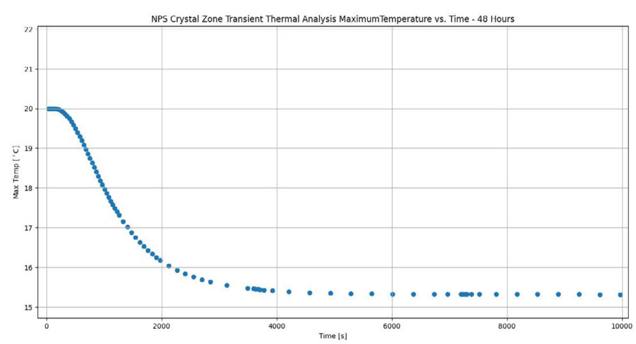

FIG. 2. Plot of maximum crystal array temperature over time.

The maximum temperature plot shows that the temperature of the crystal array reaches the equilibrium state in roughly an hour and a half.

To conclude, a transient thermal simulation of the crystal array has been conducted. The results indicate the system reaches equilibrium in roughly an hour and a half. The maximum temperature of the crystals determined by the transient analysis simulation is ~5°C lower than that determined by the steady state analysis.

[1] A. Brown et al., *Ansys Steady-State Thermal Analysis of the Engineered Cooling Design for the Hall C Lead Tungstate Crystals of the Neutral Particle Spectrometer*, DSG Note 2022-02, 2022.

[2] A. Brown et al., *Ansys Steady-State Thermal Analysis of the Engineered Cooling Design for the Hall C Lead Tungstate Crystals of the Neutral Particle Spectrometer*, DSG Note 2022-11, 2022.